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TITLE: THE EFFECT OF STRETCHING WITH CRYOTHERAPY, STRETCHING WITH HEAT, AND STRETCHING ALONE ON HAMSTRING FLEXIBILITY IN FEMALES

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ABSTRACT

Background & Aims: A Pre-and Post-intervention study was conducted to examine the effects of acute cryotherapy with stretching, heat with stretching, and stretching alone on hamstring flexibility.

Methods: Thirty female participants were randomly allocated into three groups; stretching with cryotherapy, stretching with heat, stretching without an intervention. The application of cryotherapy, heat, or no intervention to the hamstrings was conducted during a hamstring stretching routine. Sit and Reach test, and the 90/90 Active Knee Extension test were conducted before and after a 20-minute stretching routine to measure hamstring flexibility.

Findings: Differences were observed pre-and post-test in the sit and reach, and knee 90/90 extension tasks ($P<0.05$) within all three groups. However, there was no difference ($P>0.05$) between the three intervention groups.

Conclusion: Combining stretching with cryotherapy or heat application potentially provides no additional benefit to stretching alone in short-term enhancements to hamstring muscle flexibility in physically active females.

KEYWORDS: THERAPY, SPORT, LOWER-LIMB, MUSCLE, PHYSICAL ACTIVITY

KEYPOINTS:

- The effect of stretching and cryotherapy, and stretching and heat treatment on hamstring flexibility requires clarification
- Stretching alone was beneficial, but heat nor cryotherapy augmented flexibility
- Practitioners should possibly focus on using stretching interventions, without the need for additional application of heat or cryotherapy, to improve flexibility of the hamstring muscles

- Further research is required to compare the effect of different stretching protocols and heat or cryotherapy interventions, on muscle flexibility

INTRODUCTION

Flexibility is considered the ability of a joint to move freely through its full range of motion (Larsen et al. 2015), and improved flexibility has been suggested to enhance performance and decrease risk of injuries (Babault et al. 2010; Burke et al. 2001; Petersen 2005). Multiple factors can influence flexibility, including the stretch tolerance of the muscle group, the stiffness of the muscle, cross-sectional area of the muscle fibres and many other factors (Magnusson et al. 2007). Therefore, it is important to understand the best methods of improving and maintaining flexibility of the hamstring in physically active individuals.

It has been suggested that flexibility can be improved by implementing various types of stretching methods and protocols (Decoster et al. 2005). The three most common being static, proprioceptive neuromuscular facilitation (PNF) and dynamic (Woods et al. 2007). Dynamic stretching involves the use of bouncing or jerking type motions to stretch a muscle group (Amako et al. 2003). Static stretching is a slow, deliberate movement used to achieve a lengthening of the muscle (Woods et al. 2007). PNF requires the following combination of steps: a static stretch, an isometric contraction and relaxation, and then another static stretch (Amako et al. 2003). Among the different methods of stretching, static stretching is suggested to provide increased range of motion in the hamstring, when compared to PNF (Decoster et al. 2005), is a safer and more effective method (Bae et al. 2017), does not require a high level of fitness, and causes less muscle pain (Matsuo et al. 2015).

When investigating the effect of static stretching, previous literature has highlighted that there is a significant decrease in ligament and musculotendinous injuries in participants after they performed a static stretching protocol (Small et al. 2008). Other studies have observed that certain pre-exercise stretching protocols can help to reduce the risk of injuries (Woods et al. 2007). A single stretch could potentially reduce viscoelastic stress in musculotendinous structures by up to 30% (Magnusson 2007) and Whyte (2006) suggested that holding a stretch for up to 7 seconds causes activation of the Golgi Tendon Organs. The activation results in the inhibition of stretch reflexes that allows for reflex relaxation to occur, enabling the muscles and joints to be stretched further (Brukner et al. 2015). The benefits to flexibility can be further improved when stretches are held for up to 30 seconds (Depino et al. 2000; Bandy and Irion 1994), through repeated single stretch durations totalling up to 180 seconds (Ayala and De, 2010), or for a total of 90 s regardless of the number of repetitions or the duration of each individual stretch over a 6 week intervention (Johnson et al. 2014). Therefore, helping maintain and improve flexibility through stretching alone is important for physically active individuals (Woods et al. 2007).

Research developments have argued that stretching alone does not provide as great an improvement as when combined with additional therapeutic interventions, such as heat (Nakano et al. 2012). Current understanding on the effect of temperature on flexibility is mixed. Flexibility has been shown to be significantly influenced by the temperature of the soft-tissue structures (Whyte 2006). In-vitro studies indicate that heat application to muscles could increase the muscle temperature, aiding tissue extensibility, relieving muscular tension, and increasing blood flow to the area (Lehmann et al. 1974). Heat has been shown to be beneficial in increasing ligament and muscle flexibility by increasing the metabolism of the tissue, therefore helping to prepare it for the metabolic challenges involved in exercise (Lee et al. 2013). However, there have been contradictory findings when applied to physically active individuals. According to one study the combination of both heat and stretching is more effective than just stretching alone (Smith 1994); whereas Brodowicz et al. (1996) found no difference between stretching with and without heat application. These inconsistencies may be explained by differences in experimental protocols (heating application differences, muscle groups, gender, age, number of subjects) (Nakano et al. 2012). Systematic reviews revealed that heat alone does not improve flexibility (Nakano et al. 2012); however, the combination of heat and stretching could significantly improve flexibility (Bleakley and Costello 2013). Therefore, it is important to clarify the relative effectiveness of heat application on flexibility in order to appropriately inform practitioners working with physically active individuals.

Another temperature treatment where understanding is yet to be fully clarified is cryotherapy. Some studies have shown cryotherapy to have an improvement on muscle flexibility when combined with stretching (Kennet et al. 2007; Lin 2003). As a consequence of these studies, cryotherapy has been used to decrease pain, swelling and cellular metabolism (Brukner et al. 2015). Cryotherapy has also been claimed to potentially decrease muscle guarding, which could lead to improving muscle flexibility (Frontera et al. 2008). Larsen et al. (2015) examined the application of crushed ice, ice cubes and wet ice on muscle, observing that as muscle temperature decreases the nerve conduction velocity decreases, potentially resulting in an increase in range of motion. However, a systematic review by Bleakley and Costello (2013) argued that there is no conclusive evidence to prove the effect cryotherapy can have on soft issues. The authors debated that overall, the poor quality of evidence, and the small number of participants within many included studies, meant that findings should be interpreted with some degree of caution. Therefore, research is warranted to examine the effects of cryotherapy on flexibility in physically active individuals.

This study aimed to compare the effects of stretching with heat, stretching with cryotherapy, and stretching alone on hamstring flexibility. Based on previous literature, we hypothesise that stretching with heat will provide greater improvements in hamstring flexibility compared to stretching with cryotherapy. The results from this study will help determine which temperature is best coupled with stretching to provide the most beneficial effect to hamstring flexibility. This information can then be used by practitioners to help reduce the risk of injury or reduce the timescale for post injury rehabilitation.

METHODOLOGY

Participants

Thirty physically active females aged between 18-25 years (mean + standard deviation (SD) 20.69+1.59 years), with average norm scores for hamstrings flexibility of 19-20 inches (50cm) in sit and reach tests (Balady 2000), were recruited for the study. Participants were recruited if they participated in at least two to three days of recreational exercise per week. This study received prior approval from Coventry University's ethics board (Reference: P65413) and each participant was asked to complete a consent form, health screening form and given a participant information sheet before any testing took place. Each participant took part in only one intervention. Participants were randomly separated into three different groups, each contained ten participants; control (20.70+2.11 years), cryotherapy (20.90+1.60 years), and heat (20.20+0.92 years). Randomisation was done using the Research Randomizer, a program published on a publicly accessible website (www.randomizer.org). There was no significant difference between group heights ($P>0.05$).

Participants were excluded if their self-reported health screen forms revealed any medical conditions which may be aggravated by this study. Participants were excluded if they had any current lower limb injuries, a lower limb injury within the last six months or if they felt unwell. They were also excluded if they reached full 180° of knee extension during the 90/90 knee extension test.

Pre and Post Intervention Measures

In all groups each participant completed two pre-intervention tests followed by a 20-minute stretching protocol (with cryotherapy, heat or no intervention control) and two post-intervention tests in each session, completing a total of three sessions. Firstly, the Sit and Reach

Test (Eveque Sit and Reach Bench, Northwich, UK) was performed. The Sit and Reach box was placed against a wall and the participant placed both feet firmly against the box, placed one hand on top of the other pushed a marker forward and held the position for two seconds (Brodowicz et al. 1996). The distance reached was recorded. Next, the participant was asked to lie supine on a plinth, and their left hip and knee were placed into 90° of flexion. Once the hip, knee and ankle were placed at 90 degrees of flexion, the goniometer was placed beside the knee to confirm 90 degrees of knee flexion. A hand was then placed on the quadriceps above the patella to prevent any hip flexion whilst they extended the knee. Knee extension was then held for 2 seconds and in accordance with Norkin and White (2009), a goniometer (Baseline Goniometer, Transparent HiRes 360 Degree Head Fabrication Enterprises, White Plains, NY, USA) was used to measure the degree of knee extension whilst the hip maintained the 90° of flexion. The process was repeated for the right leg. The participant then completed the 20-minute stretching protocol. Once the stretching protocol was complete the Sit and Reach test and 90/90 Knee Extension test were both repeated. The researcher conducting the pre and post measurements was not blinded to each intervention group. A mean average for all three sessions were calculated for the data analysis.

<u>20 Minute Stretching Protocol:</u>

Three different passive self-stretches were applied to the hamstring muscles group, consisting of the semitendinosus, semimembranosus, and biceps femoris. For this study both supine and standing stretches were applied, Decoster et al. (2004) having suggested that a combination of stretching positions could help maximise range of motion gains, with the combination of either stretching with cryotherapy or stretching with heat. Previous literature has suggested that stretches held for 30-60 seconds improve flexibility (DePino, Webright and Arnold, 2000), and that 30 seconds were ideal (Bandy and Irion, 1994). During the first stretch, the participant was instructed to lie supine on the plinth and to keep their left leg straight while performing a straight leg raise with the right leg (Brodowicz et al. 1996). The participant when performing straight leg raise, was constantly reminded and prompted to keep the left leg straight and to not bend the knee. The second stretch involved placing their left leg on a chair whilst maintaining full knee extension in both legs (Bandy et al. 1997). The participant then bent forward whilst keeping their back straight with no thoracic or lumbar flexion of the spine (Bandy et al. 1997). The final stretch, in accordance with the method outlined by Bandy et al. (1998), involved the participant lying supine on the plinth. While keeping the right leg straight, they brought their left leg to 90° of hip flexion and 90° of knee flexion. The participant then extended their flexed knee whilst maintaining 90° of hip flexion. Once all three stretches had been performed on both legs for 30 seconds each, the participant had one minute of rest and the stretches were then repeated five times in total. The stretching protocol took 20 minutes to complete including the rest periods; overall each session lasted 40 minutes per participant.

Cryotherapy Intervention Group

Before each session began the participant had to complete a thermal sensation test (Petty & Rushton 2013). This test involved filling two disposable gloves (Latex Disposable Gloves, BM Polyco Ltd, Enfield, UK) with water; one glove was filled with warm water (not boiling) and the other was filled with cold water. The participant was asked to lie prone and expose the posterior aspect of the thigh. The warm glove was put in contact with the skin and the participant confirmed that the glove was warm; the same was done with the cold-water glove. To ensure the participants were aware of the temperature of the glove, they were then asked to close their eyes and on ten different attempts asked to state which glove was applied to their skin. To participate they had to get eight out of ten responses correct. This was performed to ensure each participant had normal responses to heat or cryotherapy, any participants who had adverse reactions or abnormal responses to the application were excluded from further testing. Before stretching began, two plastic food bags (220mmx310mm approx., Wilko, Worksop, UK) were filled with ice cubes (Polar Ice Cube Maker – G620 17KG, Bristol, UK). The full bags were then flattened so the cubes formed a flat sheet. The bags were then placed side by side on a towel and wrapped in one layer (Brodowicz et al. 1996). The participant then completed the 20-minute stretching protocol, while these bags were held against their hamstrings by the researcher.

Heat Intervention Group

Similar to the cryotherapy intervention group, before testing was conducted the thermal sensation test was conducted for every participant. Testing proceeded if they successfully got eight out of ten responses correct. For the application of heat, the Hydrocollator Steam PackMasterHeating Unit (Model E-1, Serial number 18826, Chattanooga Group, Inc., Hixson, USA) was used, with the temperature maintained between 65-70 °C (149-158 °F). The heat pack was a wheat pack that was placed in the hydrocollator an hour before the session began. Before the stretches began a heat pack was removed from the hydrocollator, placed inside a hot pack wrap and further wrapped in another towel. This towel wrapped hot pack was then held by the researcher on the participants hamstrings as the participant performed the 20-minute stretching protocol.

Statistical Analysis

Means and standard deviations for the sit and reach and 90/90 knee extension variables were calculated for all participants. The Levene statistic was used to assess the homogeneity of variance and the Shapiro-Wilk test was used to assess for data normality. A two-way repeated measures analysis of variance was performed to compare the time variables (pre vs. post) for each intervention (control vs. cryotherapy vs. heat). The intervention groups were stretching alone, stretching with cryotherapy and stretching with heat, the time variables were pre-test and post-test. The alpha level was set a priori at $P<0.05$. Post hoc testing were analysed with

Bonferroni corrections. ICC estimates and their 95% confident intervals were calculated for each dependant variable based on a mean-rating (k = 3), absolute-agreement, 2-way mixed-effects model. Sit and reach (ICC: 0.97; 95% CI: 0.944 – 0.984; P=0.00), knee extension angle right (ICC: 0.98; 95% CI: 0.782 – 0.939; P=0.00) and knee extension angle left (ICC: 0.93; 95% CI: 0.86 – 0.961; P=0.00) displayed excellent intra-rater reliability. Analysis was performed using the Statistical package for Social Sciences (SPSS 24.0 IBM Corporation, Armonk, New York, USA).

RESULTS

INSERT FIGURE 1 HERE

All variables were found to be normally distributed with equal variance. A priori power analysis indicated that you needed to have 10 participants in each group to have 80% power for detecting main effect differences of time, and 26 participants for detecting interaction effects between time and condition, when employing the P>0.05 criterion of statistical significance.

The 2 way repeated measures analysis of variance yielded a main effect for time for each of the Sit and Reach (Figure 1a) ($F(1,9) = 17.1$; $P = 0.003$; $\eta_p^2 = 0.656$), The 90/90 knee extension test scores for the left leg (Figure 1b) ($F(1,9) = 188.046$; $P = 0.000$; $\eta_p^2 = 0.954$) and the 90/90 knee extension test scores for the right leg (Figure 1c) ($F(1,9) = 942.153$; $P = 0.000$; $\eta_p^2 = 0.991$). However, the main effect for intervention was not significant for each of the Sit and Reach (Figure 1a) ($F(2,18) = 0.273$; $P = 0.764$; $\eta_p^2 = 0.029$), The 90/90 knee extension test scores for the left leg (Figure 1b) ($F(2,18) = 0.555$; $P = 0.584$; $\eta_p^2 = 0.058$) and the 90/90 knee extension test scores for the right leg (Figure 1c) ($F(2,18) = 0.277$; $P = 0.761$; $\eta_p^2 = 0.030$).

There was no significant interaction effect between time and intervention for each of the Sit and Reach (Figure 1a) ($F(2,18) = 0.605$; $P = 0.557$; $\eta_p^2 = 0.063$), and the 90/90 knee extension test scores for the left leg (Figure 1b) ($F(2,18) = 1.24$; $P = 0.313$; $\eta_p^2 = 0.121$). However, there was a significant interaction effect for the 90/90 knee extension test scores for the right leg (Figure 1c) ($F(1,9) = 17.1$; $P = 0.003$; $\eta_p^2 = 0.656$). Multiple one way analysis variance were used to investigate the significant interaction effect for the 90/90 knee extension test scores for the right leg. This analysis revealed no significant differences between interventions at either the Pre ($F(2,27) = 0.304$; $P = 0.741$; $\eta_p^2 = 0.022$) or Post ($F(2,27) = 0.529$; $P = 0.595$; $\eta_p^2 = 0.038$) intervention time points.

Post hoc analysis of the time main effect for the Sit and Reach (Figure 1a) revealed there were significant differences between the pre-intervention and post-intervention results in the cryotherapy (Pre: 21.30±9.92 cm; Post: 24.73±8.74 cm; P = 0.000), heat (Pre: 18.59±6.64 cm; Post: 22.62±6.81 cm ; P = 0.045) and control (Pre: 20.67±5.31 cm; Post: 22.87±4.31 cm; P = 0.041) intervention groups. A further post hoc analysis of the time main effect of the 90/90 knee extension test scores (Figure 1b) for the left leg showed there was a significant difference between pre-intervention and post-intervention results in the cryotherapy (Pre: 151.13±14.42°; Post: 164.37±10.94°; P = 0.000), heat (Pre: 149.34±10.15°; Post: 159.03±11.00°; P = 0.000) and control (Pre: 153.33±9.03°; Post: 165.03±10.26°; P = 0.000) intervention groups. A final post hoc analysis of the time main effect of the 90/90 knee extension test scores for the right leg (Figure 1c) revealed there were significant differences between pre-intervention and post-intervention cryotherapy (Pre: 149.70±12.24°; Post: 163.53±12.07°; P = 0.000), heat (Pre: 151.47±11.05°; Post: 159.86±11.08°; P = 0.000) and control (Pre: 153.37±7.80°; Post: 164.63±9.23°; P = 0.000) intervention groups.

DISCUSSION

The study investigated the effect of cryotherapy, heat and stretching on hamstring flexibility in 30 physically active females aged between 18-25 years old. The study aimed to identify which type of intervention with stretching was most beneficial to hamstring flexibility in order to provide practitioners with information to reduce the risk of injury or reduce the timescale for post injury rehabilitation. It was hypothesised that stretching with heat would provide greater improvements in hamstring flexibility compared to stretching with cryotherapy. The results suggested that stretching with heat, stretching with cryotherapy and stretching alone provided similar improvements to hamstring flexibility in physically active females.

Our results indicated that after the application of cryotherapy and stretching, significant improvements were observed in measures of hamstring flexibility. These improvements in measures of hamstring flexibility were observed to be similar to stretching alone and heat application. These results support previous investigations in males (Cornelius et al. 1992) and elderly females (Rosenberg et al. 1990), which showed that cryotherapy and stretching was no better than stretching alone. These are in contrast to other research which suggested cryotherapy could provide short term enhancements in hamstring flexibility when compared to a control group (Brodowicz et al. 1996; Larsen et al. 2015). These investigations into cryotherapy and stretching techniques may have shown different results due to the stretching routine prescribed. Larsen et al (2015) used a proprioceptive neuromuscular facilitation (PNF) using the slow-reversal-hold-relax (SRHR) technique, whereas in the current study a series of static stretches were utilised. At skin temperatures of 13.6 ° C (Herrera et al. 2010) there is a 10% decrease in muscle nerve conduct velocity. Decreasing nerve conduct velocity increases the latency and duration of the action potentials in motor and sensory nerves, while decreasing the amplitude of the action potentials to produce a greater stretch (Herrera et al. 2010). Improvements in ROM could also be related to an increase in the pain threshold because of the analgesic effect and muscle nerve conduct velocity change (Larsen et al. 2015). Using a SRHR technique may enable a greater stretch when compared to a series of single static stretches due to the increased pain threshold and decreased muscle nerve conduct velocity. Therefore, different stretching techniques could respond differently to cryotherapy and further research is needed to examine any potential differences (Bhattacharjee et al. 2016; Witvrouw et al. 2004). Nevertheless, while the benefits of cryotherapy are yet to be fully elucidated, therapists should focus on using appropriate stretching methods rather than cryotherapy to improve short-term flexibility in the hamstrings.

In support of previous research, the combination of heat and stretching did provide significant improvements to the hamstring flexibility (Nakano et al. 2012). However, our results did not indicate any significant ($P>0.05$) improvements in hamstring flexibility between the heat intervention group, and the control or cryotherapy groups. The heat applied may not have penetrated the muscles to the extent that heat could have influenced the activity of the muscle. Hot pack treatments have, compared to other methods of heat application such as Ultrasound (Draper and Richard, 1995), appeared to result in smaller differences for the larger muscle groups (hamstrings, triceps surae) (Nakano et al. 2012). Therefore, rather than use the more cost effective methods of heating muscle, such as heat pads, practitioners should potentially focus on using appropriate stretches to improve short-term flexibility.

The results from the cryotherapy and heat group were observed to be similar to those in the control group, suggesting that stretching provided the main effect on increasing hamstring flexibility short-term. Our study has provided further evidence that supports previous literature of the benefits of stretching for flexibility (Ayala and De, 2010; Johnson et al. 2014; Depino et al. 2000; Bandy and Irion 1994). Stretching can help increase dynamic flexibility, which reduces a joint's ability to move beyond its maximum range of static flexibility that can result in the occurrence of injuries (Whyte 2006). This can be done by activating the golgi tendon organ, inhibiting the stretch reflex and allowing a reflex relaxation and subsequently the muscle/joint can be stretched further (Whyte 2006). The results of the current study support the implication for practitioners that it is possible to increase short-term flexibility of the hamstring in physically active females by providing a 20 minute hamstring-specific static stretching routine. Furthermore, it appears to confirm that it is equally effective as techniques involving heat application and cryotherapy.

Limitations

To further understand the effects of cryotherapy or heat with stretching, future research may need incorporate more accurate forms of measuring hamstring flexibility. Although hand held goniometers demonstrate high inter and intra-rater reliability and a good level of accuracy (Hancock et al. 2018), they are not the gold standard. Incorporating 3D motion capture or radiographs would enable a more accurate representation of the range of motion of the hamstring muscles. A further limitation was that the type and amount of exercise, past injury history, menstrual phase, and internal or external individual factors of the participants was not recorded. These factors may have resulted in individual variations in flexibility measurements and adaptations to the treatment intervention. A final limitation of the study was that the current study was underpowered when investigating the interaction effects of time and condition, therefore future studies should ensure that they are appropriately powered.

CONCLUSION

In summary, this study demonstrated that combining stretching with cryotherapy or heat application potentially provides no additional benefit to stretching alone in short-term enhancements to hamstring muscle flexibility in physically active females. Practitioners should possibly focus on using traditional stretching interventions, without the additional application of heat or cryotherapy to improve short-term flexibility of the hamstring muscles. Further research is needed to compare the effect of different stretching protocols and heat or cryotherapy interventions, on hamstring flexibility.

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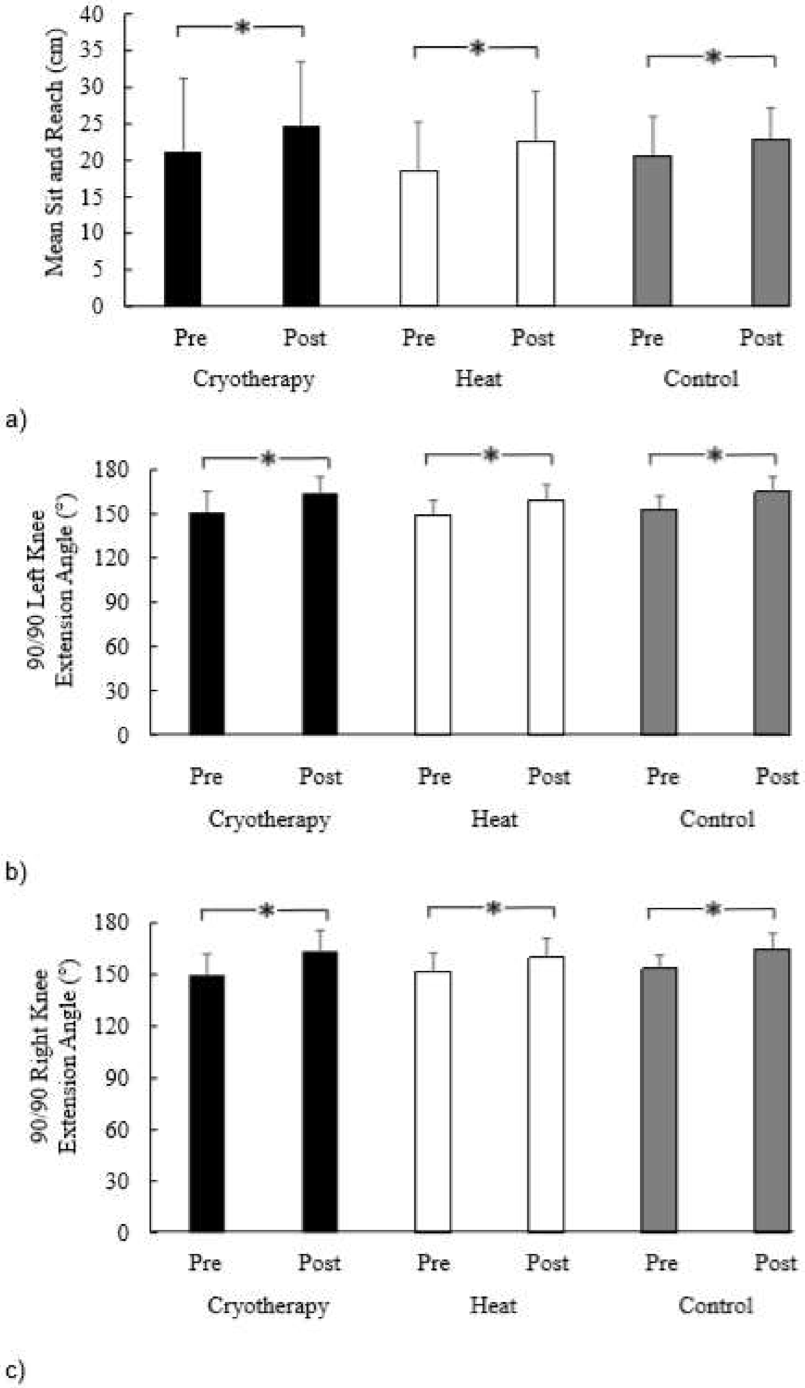

Figure 1. The Mean (±SD) scores for the Sit and Reach Test, and the right and left leg 90/90 knee extension tests for pre-and post-intervention in the Cryotherapy (n=10), Heat (n=10), Control (n=10) groups. *Significant difference between pre and post intervention ($P < 0.05$).